CHAPTER VII
CHAPTER VII
CONCLUSION AND APPLICATIONS

The present study was undertaken keeping in view the mineralogical and geochemical changes which occur at the time of explosion due to tremendous heat in respect of quantity of explosives used, type of target and mixture of various explosives used in experimentation with clay soil as the medium.

In this section of work, the author presents a resume of salient conclusions which may be used in finger printing the explosives, identification of site of explosion and other related parameters i.e. quantity of explosives used - single explosive or mixture of explosives - different targets etc. on clay soil. The Chapter wise conclusions are as under:

It can be seen from the chemical examination mentioned in Table no: 10 to 13 that the development of pink to red colour by the Griess reagent indicates the presence of nitrate and nitrite. It can be seen that the Griess reagent though develops red colour in RDX and PETN,
there is no development of colour in soil samples exploded by TNT. Thus, as expected if Griess test is not positive then no Nitrate, nitrite or nitro containing organic compounds are present with the exception of TNT. Likewise reagent DPA when treated on exploded soil samples, developed blue colour for RDX and PETN with the exception of TNT. Reagent alcoholic KOH when treated on exploded soil samples, developed red colour only in case of TNT exploded soil sample. It is evident from the table no:10 to 13 that irrespective of the targets and arrangements for explosions the screening test by Griess reagent, Diphenylamine and alcoholic KOH reagent can conveniently be adopted for elimination or before confirmation by other methods. (Yinon, and Zitrin, 1993., Moitra, Prasad, and Bami.,1978).

It can be seen from the results of the TLC examination mentioned in the Tables 14 to 20 that the colour reaction produced by RDX, TNT, PETN (Kirchmer, J.G. 1975a) have shown positive results. Rf values obtained by TLC Table 14 and 15 are the same as that of the standard sample of TNT, under similar condition, Table 16,17,18 have shown the Rf value similar to that of standard sample of RDX, the RF values given in of Table 19 are similar to that
of the standard sample of TNT and RDX, while Rf values in Table 20 are same as that of the standard sample of PETN. This also agreed with that of reported in literature. (Yinon, and Zitrin., 1993).

In the FTIR analysis λ max. was found same as that of the standard (known) RDX, PETN and TNT explosive samples. There by indicating positive results irrespective of the quantity, time lapse and type of target involved in the explosion.

It can be seen from the results of pH examination mentioned in (Table no:22) that "the control soil sample" having pH 6.5 was slightly acidic in nature, nearer to the neutral. All post explosion soil samples (nos.1 to 48) were basic with the pH ranging between 8 and 8.4. Evidently the variation in pH values between the pre- and post- explosion samples should have resulted from the explosions. A considerable change in pH value of the soil samples after explosion is demonstrated, which might be dependent upon cation- anion exchange reactions, burning of acidic soil on account of high temperature due to explosion and other acid- base reactions in high temperature-
It has been observed from the results of colour examination mentioned in Table no: 23 to 26 that the brown colour of the original soil samples collected before explosion, as expected, changed post explosion to a variety of shades of brown such as: grayish brown, pale yellow brown, cherry red brown and dark brown. Evidently this change in colour is due to the effect of explosion on the soil at the site and its surrounding such as vegetation etc.

A comparative study of the density distribution of soil particles (Fig.G) observed in the control soil samples with those of post-explosion soil samples (Nos.1-48) revealed that there was change in the distribution pattern of particles. The change in the distribution pattern of particles exhibited by post-explosion soil samples is apparently due to the effect of explosion on the soil, because during explosion a very high temperature (3000°-5000°C) is developed. The organic constituents, micro-organisms, moisture content, vegetation etc. in the soil are influenced to a great extent due to the excessive heat of blast of the explosion resulting into adsorption
and adsorption of the explosive vapors and their escape. These may result in chemical, physical and crystallochemical changes in the mineral constituents of the soil and other particulate matter influencing the density distribution of the particles in the density gradient glass columns. Therefore, as expected, the density distribution of particles of soil samples from the site of explosion was different from that of the control (pre-explosion) soil sample.

It can be seen from the results (fig.G') that weight loss is the least in control soil sample as compared to the other post explosion soil samples with different explosives having different quantities and targets. It is clear case of increase in weight loss showing in the order-control, RDX+TNT, TNT(breach charge),TNT(Pressure charge), EDX(2.00kg) RDX(11.3,3.1 kg). PETN has also shown similar pattern. It is depicted that the weight loss i.e. ignition percentage is due to moisture. Evidently this change is due to effect of heat of explosion on soil.

From the results of the XRD and FTIR analysis mentioned in Table nos: 32 to 35, 36 to 38 and 39, it is evident by now that the studied clay mineralogy, if
determined precisely by sophisticated analytical technique like XRD and FTIR spectrometer etc., leading to the identification of phases containing Al, Fe, Ca, Mn, Mg, etc. (Phyllosilicates and oxides and hydroxides) constituting the soil, may help in forensic investigations in two ways i.e. finger printing the explosives and site of explosion, at the minimum. During the present study, it has been observed that the new array of minerals in post explosion samples (S.N. 1 to 48), which did not occur in the pre-explosion (Control) soil samples are mostly the legitimate resultant refractory minerals or high temperature transformations / modifications or polymorphs of those observed in the later (CS). These minerals are high-temperature polymorphs of quartz (SiO₂), usually found in fissures of acid affusives (volcanic) rocks, i.e., Cristobalite and Tridymite. The Al-bearing minerals like Mullite (3Al₂O₃·2SiO₂), Boehmite [γAlO(OH)], polymorphs: Sillimanite (Al₂O₃·SiO₂) and Kyanite (Al₂O₃·SiO₂), Fire clay [Al₂(OH)₄Si₂O₅] - a refractory mineral of Kaolinite composition, Pyrophyllite [Al₂Si₄O₁₀(OH)₂] and Fe-bearing minerals i.e. Lepidocrocite [γ-FeO(OH)] and Goethite [α-FeO(OH)] are the new high temperature assemblages. The Mg-bearing minerals again of similar genetic history (heating
resulting in swelling) or as evaporites) are Talc \[ \text{Mg}_3\text{SiO}_4\text{O}_{10} (\text{OH})_2 \], Chlorite \[ (\text{Mg, Fe})_5 \ (\text{Al, Fe})_2\text{Si}_3\text{O}_{10} (\text{OH})_3 \] and Gypsum \((\text{CaSO}_4.2\text{H}_2\text{O})\). Mullite withstands high temperature (upto \(1800^\circ\text{C}\)) and is a fusion product of Kaolinite \[\text{Al}_4 \text{Si}_4\text{O}_{10} (\text{OH})_8\]. Mullite, is obtained by heating \(\text{Al} - \text{hydroxide} + \text{quartz}, \text{Sillimanite}, \text{andalusite} \) or \(\text{Kyanite} \) at about \(1500^\circ\text{C}\). Also by heating \(\text{pyrophyllite, montmorillonite} \ [\text{Al}_4\text{Si}_8\text{O}_{20} (\text{OH})_4 \text{_n_}_\text{H}_2\text{O}], \text{muscovite} \ [\text{kAl}_3\text{Si}_3\text{O}_{10} (\text{OH})_2], \) and \(\text{illite} \ [\text{K}_y (\text{Al}_4\text{Fe}_4 \text{Mg}_4 \text{Mg}_6) (\text{Si}_{8-y} \text{Al}_y) (\text{OH})_4] \) at about \(1000^\circ\text{C}\), mullite \(3\text{Al}_2\text{O}_3.2\text{SiO}_2\) is formed. All these processes of formation have been discussed by the author in the preceding chapter on mineralogy. Some salient characteristics of forensic significance are outlined below:

In case of TNT - exploded soil sample - Gypsum (an evaporite \(\text{CaSO}_4.2\text{H}_2\text{O} \) mineral) + Mullite + Goethite are present. The first one indicates lower temperature (evaporation) phase.

In case of PETN - exploded soil sample - very high temperature mineral phases are diagnostic i.e. Cristobalite, Lepidocrocite, Kyanite, Fire clay, Boehmite +Mullite + Goethite + Chlorite. This assemblage is probably
the highest temperature one from amongst the explosives (TNT, RDX, PETN and RDX+TNT) used during the present investigation.

In case of RDX- exploded soil sample - the resultant mineral assemblage characterizing this system are Sillimanite, Talc, Pyrophyllite + Kyanite + Mullite.

In case of RDX+TNT - exploded soil sample, the significant mineral phases are Tridymite + Mullite + Lepidocrocite + Kyanite. There is scope for further experimental investigations and the data presented in this work may open up new vistas in the field of Forensic Geology.

The author used a very sophisticated analytical technique i.e. ICP spectrometry for determination of elemental (Al, Fe, Mn, Ca, Mg, Na, Zn, Cr, Ni, Cu) composition of the pre-explosion (Control) soil sample as well as the post- explosion soil samples (S.N. 1 to 48). A comparative study of these elemental data brings out pattern / trend of elemental distribution during the experimental explosions in ambient conditions, that is, an open system. Further, the researcher attempted to decipher quantitatively the loss and gain in elemental contents (post- explosion soil samples) in comparison to the composition of the pre- explosion soil samples (CS). All
these data have been plotted and presented in Chapter V and discussed in the preceding section.

Addition of elements as reflected in the post-explosion (TNT, RDX, PETN, RDX+TNT) Soil samples data could be explained to some extent by considering the experimental conditions in terms of charge, mode of detonation, explosive mixtures etc. As against this, the loss of elements may not be explained particularly as observed in case of PETN - exploded soil samples, where in only detonator has been used. No addition (enrichment) of elements have been noticed but for the depletion in the concentration of all elements vis-à-vis the elemental composition of the (CS). Nothing positive can be identified in terms of finger printing of the explosives, exception probably being PETN (heat of explosion, 1510-1529 cal/kg). Some valuable information may be forthcoming based on intensive experimentation using precisely defined parameters, exact composition of all the explosives, charge, additives detonators etc. and by determining the composition of the gaseous constituents, precise reactions taking place - their kinetics and step-wise products. The author has appreciated the constraints and is of the view that much work is needed to achieve the stage of geochemical finger printing. Isotopic (stable isotope ratio
e.g. $^{32}\text{S}/^{34}\text{S}$; $^{18}\text{O}/^{16}\text{O}$; $^{13}\text{C}/^{12}\text{C}$) studies, tracer (element) investigations, mobility of ions in such an artificial, high temperature – high pressure system, leading quickly to sudden loss of heat and pressure, and determination of elemental composition phase wise i.e. mineral species-wise (initial and resultant products) can help in defining some geochemical parameters of forensic significance. The significance of present investigation, on the whole, lies in obtaining well-researched set of pioneering data which could be useful and essentially in bringing this aspect of Forensic study on the anvil.

One important observation is that the collected soil sample can be used even after a lapse of several years without any change in their mineralogical and geochemical compositions, thereby ensuring positive results. The tenability of the evidence (in explosion cases) in absence of other clues, is thus enhanced and therefore it is explosive signature – a feature showing a positive and unique indication that an explosive detonation has occurred in the soil at that particular site. Any such signature is sufficient to prove that an explosion occurred.